

Logging Roads and Aquatic Habitat Protection in the California Redwoods

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Introduction

Control of sediment from logging roads in California's redwood region is important to protecting streams inhabited by endangered salmonids. Both private and public landowners have limited resources to devote to road erosion control, and must make difficult choices about which roads to treat and how to treat them. We are developing operations research models to address road management questions in both spatial and temporal terms. These models explore the management implications of ongoing erosion, stochastic failures, and option values such as the ability to use roads for fire control and other management activities. Four decades of data collection and research on precipitation, hydrologic function, and sediment loads in the Caspar Creek watershed provides an information base on which to build such models (Ziemer 1998). Our goal is to produce decision tools useful to both public and private land managers who want to achieve cost-effective reduction of sediment delivery from roads to streams.

An Example: Road 630

Road 630 on the Jackson Demonstration State Forest in Mendocino County, California, is an unused logging road. A recent inventory of erosion potential on the road suggests that both mass wasting (landslides or stream crossing failures) and chronic surface erosion are likely to deliver significant volumes of sediments to nearby Caspar Creek. Forest managers face the question of how to achieve cost-effective reduction of sediment delivery from this road—in particular whether to maintain the road as it is, to upgrade the road by removing culverts and sloping the road outward, or to remove the road entirely, including exporting unstable material.

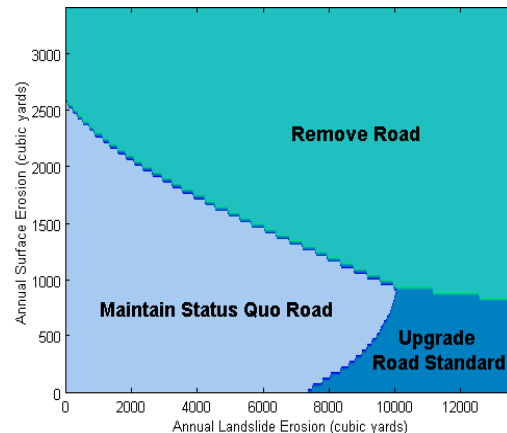
Figure 1: This road crossing failure on Road 630 delivered sediment directly to the stream network.



A Decision Model for Road 630

A decision model was developed using stochastic dynamic programming, an optimization technique that explicitly incorporates uncertainty, system dynamics, and the option to delay important decisions while gathering more information. In this framework, road management is treated as a Markov decision process, meaning the probability distribution function of future erosion is conditional only on the current erosion level. Implementing this type of model requires information on erosion processes and risks, periodic erosion control costs, and the lump-sum costs of road upgrade or removal.

Figure 2: The optimal road management decision depends on the levels of observed road surface and landslide erosion.



The figure above shows the results of a prototype model in which the goal is to minimize the expected value of future erosion control costs. Expected future total erosion is assumed to be conditional on current surface erosion but not on current landslide erosion, i.e., landslides are assumed to be serially independent. At low levels of surface and landslide erosion, maintaining the *status quo* road is preferred since it avoids the lump-sum costs of road upgrade or removal. The boundary between maintaining the *status quo* road and removing the road slopes downward because, as surface erosion decreases, the expectation of future total erosion falls, making road removal relatively less attractive. That is, lower levels of current surface erosion require higher levels of landslide erosion to justify the expense of road removal. The boundary between maintaining the *status quo* road and upgrading to a higher road standard slopes upward, reflecting the relatively greater likelihood, as surface erosion increases, that the road will have to be removed later. That is, as the likelihood that a road will later be removed increases, it becomes progressively less desirable to pay the lump-sum costs of upgrading that road.

Figure 3: A plugged culvert can cause stream diversions with the potential for significant sediment delivery to streams.



Assessment

What do we know and not know about controlling logging road erosion in coastal California watersheds?

Quite a lot is known about precipitation, hydrologic function, and sediment processes in some coastal California streams (e.g., Ziemer 1998). With experience in maintaining, upgrading, and removing logging roads—such as the intensive program of road erosion control on Redwood National and State Parks—understanding of the relative effectiveness of different erosion control measures is growing (Madej 2001). Data on road erosion are relatively scarce in comparison with those on sediment loads in streams, making the attribution of erosion to particular sources difficult. While there is general agreement that a small number of large mass wasting events is responsible for most road erosion, the likelihood of failure for a given unstable site is difficult to estimate with current techniques (Krogstad 2001, Lewis and Rice 1990).

Can models help improve road erosion management?

While the costs of erosion control are generally estimable, the benefits and risks are more difficult to quantify. For example, the benefits of keeping a given road open depend on its function in the road network, so in many cases it is inappropriate to consider a single road in isolation. Lack of data on road erosion rates, and the difficulty of assessing the risk associated with individual unstable sites, are serious challenges to developing useful road management models. We are extending the dynamic model described above to address networks of roads and the range of benefits associated with logging roads. Such quantitative models are a supplement to, not a substitute for, the judgment of forest managers with knowledge of local conditions.

References

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